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Design, Synthesis, Characterization and Pharmacological Evaluation of Novel Imidazole-Based Oxazolone Derivatives as Potential Analgesic and Anti-Inflammatory Agents

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Abstract:
The study was undertaken to design, synthesize, characterize, and evaluate novel imidazole-based oxazolone derivatives (OXA01–OXA09) possessing two pharmacophoric systems with the goal of identifying new analgesic and anti-inflammatory lead compounds. A systematic research plan was followed that included molecular design, multi-step organic synthesis, purification, analytical characterization, in vivo pharmacology, in vitro cytotoxicity, and molecular docking. Oxazolone derivatives were synthesized via cyclodehydration of benzoylglycine intermediates with various substituted aryl aldehydes in acetic anhydride–sodium acetate under catalytic ZnO. All intermediates and final compounds were purified and structurally confirmed by TLC, melting point analysis, IR, $^{1}H/^{13}C$ NMR, LC–MS, and elemental analysis, confirming successful formation of the intended oxazolone scaffolds. Acute oral toxicity studies in rodents revealed no mortality or severe toxic symptoms up to 2560 mg/kg, indicating high safety margins and LD_{50} greater than 2560 mg/kg, classifying the compounds as low-toxicity agents. Most derivatives demonstrated dose- and time-dependent analgesic activity, with OXA03, OXA05, OXA07, and OXA09 showing the strongest effects, in some cases comparable to or exceeding standard drugs (indomethacin and diclofenac). Compounds such as OXA08 and OXA02 also demonstrated moderate yet meaningful activity.
Keywords: OXA03, OXA05, OXA07, meaningful activity, pharmacology, in vitro cytotoxicity

Introduction

Imidazole derivatives

Imidazole is a five-membered nitrogen-containing ring. It is widely found in nature, including in amino acids such as histidine. Because of their structural similarity to biological molecules, imidazole derivatives can easily participate in hydrogen bonding and interact favorably with enzymes, making them valuable structural units in drug design. Compounds containing imidazole rings have demonstrated anticancer, anti-inflammatory, antimicrobial, and enzyme-inhibitory activity.

Oxazolone derivatives

Oxazolones represent another class of heterocyclic compounds that are known for their medicinal value. They have been associated with analgesic, anti-inflammatory, antimicrobial, antioxidant, and anticancer activities. Their ring system allows them to bind selectively within enzyme active sites, including COX-2. Because both imidazole and oxazolone rings exhibit biological activity independently, combining these two pharmacophores into a single hybrid molecule may improve pharmacological performance. This forms the basis of the present research.

Rationale for the Present Study

Developing new NSAID-like compounds requires designing molecules that:

1. retain strong pain-relieving and anti-inflammatory effects
2. selectively target COX-2
3. reduce gastrointestinal and systemic toxicity
4. possess favorable pharmacokinetic properties

Based on literature findings, benzimidazole-based oxazolone derivatives appear to satisfy these requirements. Their structures allow multiple types of chemical interactions within enzyme binding pockets, including hydrogen bonding, π–π stacking, and hydrophobic interactions.

The present study, therefore, focuses on:

- synthesizing a series of novel oxazolone derivatives (OXA01–OXA09)
- characterizing their structure
- testing their toxicity and analgesic effects in laboratory animals
- evaluating their binding affinity with COX-2 using molecular docking

This integrated approach links synthetic chemistry, pharmacology, and computational modeling to identify promising drug candidates.

Materials and Methods

Materials and Reagents

The chemicals and reagents used in the present investigation were of analytical grade and were procured from reputed suppliers such as Merck, Sigma-Aldrich, and SD Fine Chemicals. All solvents used in moisture-sensitive reactions were dried prior to use, and anhydrous conditions were maintained using $CaCl_2$ guard tubes wherever necessary.

Standard borosilicate glassware was employed for all experimental procedures.

Chemical Reagents:

Benzil, substituted aryl aldehydes (for OXA01–OXA09), 4-(4,5-diphenyl-1H-imidazol-2-yl)benzoyl glycine, acetic anhydride, anhydrous sodium acetate, zinc oxide, silver triflate, ammonium acetate, carboxybenzaldehyde, thionyl chloride, glycine, sodium hydroxide (NaOH), potassium hydroxide (KOH), chloroacetyl chloride, ethyl chloroformate, morpholine, N-bromosuccinimide (NBS), hydrazine hydrate, ethyl chloroformate, primary amines (A–L), petroleum ether, ethanol, dichloromethane (DCM), ethyl acetate, chloroform, dimethyl sulfoxide (DMSO), and other routinely used organic solvents.

Biological Reagents:

RPMI-1640 medium, DMEM high glucose medium, MTT reagent, Triton-X100, trypan blue dye, and 0.9% NaCl physiological saline. All chemicals were stored under recommended conditions, and fresh solutions were prepared wherever necessary.

Synthetic Methodology — Oxazolone Series (OXA01–OXA09): A series of (E)-4-benzylidene-2-(4-(4,5-diphenyl-1H-imidazol-2-yl) phenyl) oxazol-5(4H)-one derivatives (designated as OXA01–OXA09) was synthesized through a multi-step synthetic sequence involving the preparation of key intermediates followed by dehydrative cyclization. The synthetic strategy involved the condensation of appropriately substituted aryl aldehydes with 4-(4,5-diphenyl-1H-imidazol-2-yl)benzoyl glycine under acetic anhydride–sodium acetate mediated cyclodehydration. A catalytic amount of zinc oxide (ZnO) was employed to enhance the rate of the cyclization and improve product yield. The overall methodology provided an efficient route to structurally diverse oxazolone derivatives, tailored by variation of the aryl aldehyde component.

Preparation of 4-(1H-benzimidazol-2-yl)benzoic acid:

Intermediate 4 was synthesized via a modified one-pot condensation reaction. In a 50 mL four-neck round-bottom flask (RBF) equipped with a condenser, thermometer, and magnetic stirrer, benzil, carboxybenzaldehyde, and ammonium acetate were dissolved in 25 mL of ethanol. To this homogeneous mixture, a catalytic amount of silver triflate (AgOTf) was added to initiate benzimidazole ring formation. The reaction mixture was heated to 70 °C with continuous stirring. Reaction progression was monitored periodically by TLC using petroleum ether:ethyl acetate (6:4) as the mobile phase. Upon completion of the reaction, the mixture was allowed to cool, and the catalyst was removed by filtration. The filtrate was extracted with ethyl acetate, washed successively with saturated sodium bicarbonate solution ($NaHCO_3$) and distilled water to remove acidic and water-soluble impurities. The organic phase was then dried over anhydrous sodium sulfate, filtered, and concentrated under reduced pressure. The crude residue obtained was purified by recrystallization from ethanol, yielding Intermediate 4 as a pale red crystalline solid (yield: ~84%; melting point: 247–249 °C). The structure and purity of Intermediate 4 were confirmed by IR spectroscopy, ^{1}H NMR, ^{13}C NMR, LC–MS, and elemental analysis, and matched values required for the intended synthetic pathway.

Conversion to Benzoyl Chloride

Intermediate 4 was converted into the corresponding acid chloride (Intermediate 5) to enable subsequent amide formation. Intermediate 4 was dissolved in 25 mL of dry dichloromethane (DCM) in a round-bottom flask. Thionyl chloride ($SOCl_2$) was added dropwise with continuous stirring, maintaining the reaction temperature at approximately 40 °C. The progress of the reaction was monitored by TLC using petroleum ether:ethyl acetate (5:5) as the mobile phase. After complete conversion, excess thionyl chloride and solvent were removed by rotary evaporation under reduced pressure to afford the acid chloride Intermediate 5. The product was used directly in the next step or further characterized. The crude material displayed a melting point of 221–223 °C, consistent with the expected acid chloride.

Synthesis of Benzoylglycine

To obtain benzoylglycine (Intermediate 6), glycine (0.11 mol) was dissolved in 25 mL of 10% aqueous NaOH solution in an ice bath. The previously prepared acid chloride (Intermediate 5) was added gradually in portions with vigorous shaking or stirring to maintain uniformity. After complete addition, the reaction mixture was acidified by adding concentrated hydrochloric acid over crushed ice, which induced precipitation of benzoylglycine. The solid product was collected via suction filtration, washed thoroughly with cold water, and recrystallized from ethanol to yield pure Intermediate 6 suitable for the subsequent oxazolone formation step.

Pharmacological and Biological Evaluations

A comprehensive battery of in vivo and in vitro biological assays was performed to evaluate the analgesic and cytotoxic potential of the synthesized compounds from both the Oxazolone series (OXA01–OXA09). All experimental procedures adhered strictly to CPCSEA/IAEC ethical guidelines.

Acute Oral Toxicity (OECD425—Up-and-Down Procedure): Acute toxicity studies were conducted in female Albino Wistar rats weighing 150–200 g, following the internationally accepted OECD Guideline 425 (Up-and-Down method). Prior to dosing, animals were fasted overnight with free access to water to enhance absorption and minimize variability. Test compounds were administered orally at escalating dose levels: 40, 80, 160, 320, 640, 1280, 2560, and 5120 mg/kg, prepared freshly in an appropriate vehicle.

Control animals received distilled water (10 mL/kg).

Observations and Monitoring

Animals were observed:

- Continuously for the first 1 hour,
- Intermittently for the next 4 hours,
- Periodically up to 24 hours,
- And daily for 14 days thereafter.

Behavioral and physiological signs of toxicity were carefully recorded, including: Hypoactivity, piloerection, salivation, syncope, tremors, altered respiration, convulsions, and body weight loss. Any mortality occurring during the observation period was noted for LD_{50} determination. The LD_{50} values were estimated using the arithmetic method of Karber, where mortality data allowed meaningful calculation.

Analgesic Activity — Oxazolone Series

Both central and peripheral analgesic models were used to evaluate analgesic efficacy.

A. Tail Immersion Test — Central Analgesia

This assay was conducted in Wistar rats (n = 6 per group) using standard procedures.

Treatment Groups:

- Control: saline (0.1 mL)
- Standard: Indomethacin (30 mg/kg, p.o.)
- Test groups: OXA derivatives at 50 mg/kg and 100 mg/kg, p.o.

The distal portion of the tail (1–2 cm) was immersed in water maintained at 55 °C, and the withdrawal latency was measured at: 0 (baseline), 15, 30, 45, and 60 minutes post-treatment.

The percentage analgesic activity (PAA) was calculated using:

$$\mathrm{PAA} = \left(\frac{T_2 - T_1}{T_2}\right) \times 100$$

Where T_1 = baseline latency and T_2 = post-treatment latency.

B. Acetic Acid–Induced Writhing Test—Peripheral Analgesia

Peripheral analgesic activity was evaluated in Swiss albino mice (n = 6/group). Animals received test compounds or standard 30 minutes before intraperitoneal injection of 0.6% acetic acid (0.1 mL per 10 g body weight).

Standards: Diclofenac sodium (5 mg/kg, p.o.).

The number of writhes (stretching, arching, or torso elongation) was counted for 15 minutes.

This model reflects peripheral analgesia through inhibition of prostaglandin synthesis.

Data Analysis and Statistics

All quantitative data were expressed as Mean ± SEM.

Sample sizes were:

- n = 6 for in vivo studies
- n = 3 for in vitro experiments (triplicates)

Before applying parametric tests, Bartlett's test was used to assess homogeneity of variances.

Statistical Tests

- For datasets meeting homogeneity criteria, one-way ANOVA was applied.
- Post hoc comparison to control groups was conducted using Dunnett's test.
- For datasets with non-homogeneous variance, appropriate transformations (log, square-root, or reciprocal) were performed.

Result and Discussion

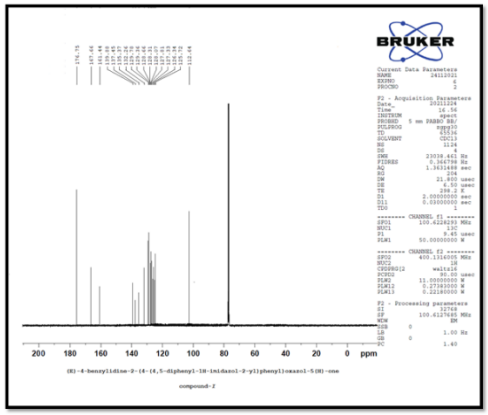
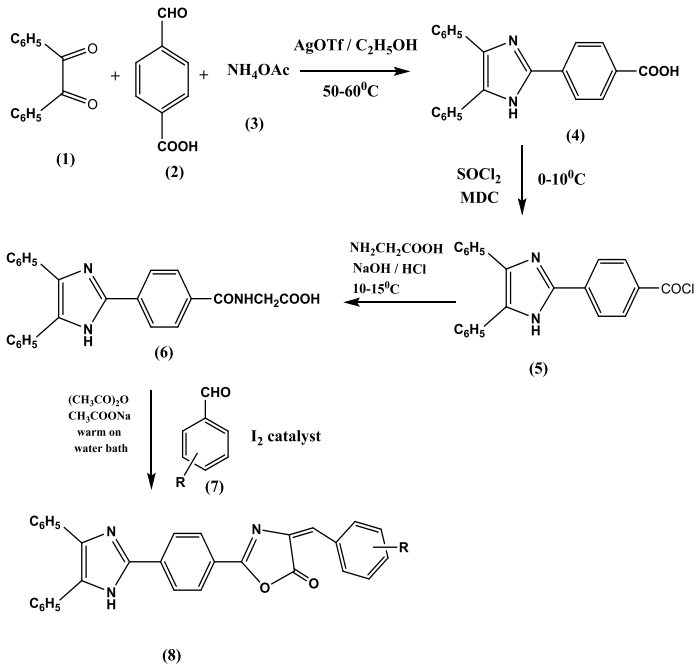
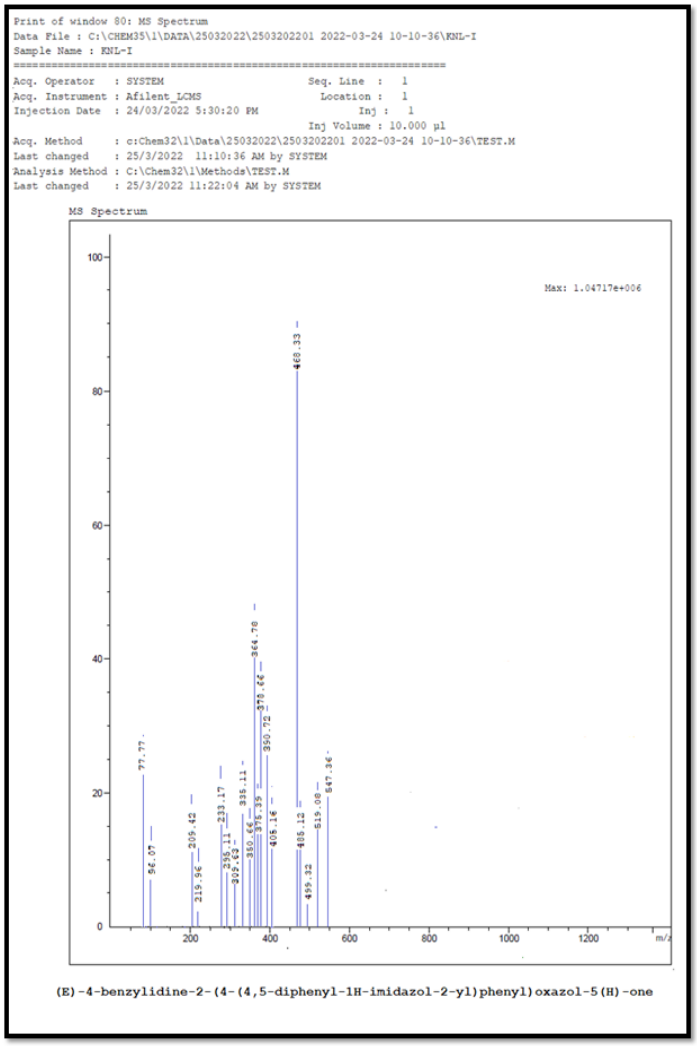


Figure 2: NMR- Spectrum



R = H , 4-OH , 4-OH-3-OCH_3 , 4-$N(CH_3)_2$, 4-F , 4-Cl, 4-Br , 4-CN , 4-NO_2

Figure 1: Scheme of Oxazolones-I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Data File : C:\CHEM35\1\DATA\25032022\2503202201 2022-03-24 10-10-36\KNL-I
Sample Name : KNL-I
Acq. Operator : SYSTEM
Seq. Line : 1
Acq. Instrument : Afilent_LCMS
Location : 1
Injection Date : 24/03/2022 5:30:20 PM
Inj : 1
Inj Volume : 10.000 µl
Acq. Method : c:Chem32\1\Data\25032022\2503202201 2022-03-24 10-10-36\TEST.M
Last changed : 25/3/2022 11:10:36 AM by SYSTEM
Analysis Method : C:\Chem32\1\Methods\TEST.M
Last changed : 25/3/2022 11:22:04 AM by SYSTEM
MS Spectrum
Max: 1.04717e+006
(E)-4-benzylidine-2-(4-(4,5-diphenyl-1H-imidazol-2-yl)phenyl)oxazol-5(H)-one

Figure 3: MASS- Spectrum

Acute toxicity study

The general behavioral changes of rats were carefully observed following the oral administration of the synthesized compounds. At a dose level of 2560 mg/kg body weight, the compounds produced dose-dependent effects. At lower doses (≤1280 mg/kg b.wt), no abnormalities were observed in fur texture, eye color, behavioral or neurological profiles, and no mortality was recorded. The morphology and behavior of the treated animals remained comparable to those of the control group throughout the observation period. At the highest administered dose (2560 mg/kg b.wt), the compounds produced only mild hypoactivity, with the intensity of responses increasing with dose escalation. These effects were transient and persisted for more than 2 hours post-administration, after which the animals recovered to normal activity levels. Importantly, no mortality or significant tissue damage was observed across any dose groups during the 14-day observation period. Since no death occurred throughout the acute toxicity study, the LD_{50} value could not be determined and was considered to be greater than 2560 mg/kg body weight (Table XXX).

Table 2: Acute Toxicity Studies of synthesized (Oxazolones) compounds.

Treatment	Dose (mg kg-1 b.wt)	D/T	Mortality latency (h)	Toxic symptoms
Control	-	0/3	-	None
OXA01	2560	0/3	-	None
OXA02	2560	0/3	-	None
OXA03	2560	0/3	-	None
OXA04	2560	1/3	36-48	Salivation
OXA05	2560	0/3	-	None
OXA06	2560	0/3	-	None
OXA07	2560	0/3	-	None
OXA08	2560	1/3	36-48	Salivation
OXA09	2560	0/3	-	None

D/T = Dead/Treated rats; none = No toxic symptoms during the observation period; mortality latency = time to death after oral administration. Compounds were administered to two groups of rats. Rats in each group were carefully examined for any signs of toxic (behavioural changes and mortality) for 14 days.

Table 3: Oxazolones of Analgesic activity by Tail Immersion Method

Treatment	Dose mg/kg	Basal Reaction Time	Reaction time in sec's (% Analgesic activity)			
			15Min	30Min	45Min	60Min
Normal Saline	0.1ml	2.24±0.24	12.31±0.14	12.34±0.27	12.38±0.12	12.42±0.15
Indomethacin	30	2.26±0.16	12.34±0.28 (13.41)	16.65±0.24 (76)	17.45±0.34 (79.66)	18.98±0.24 (85)
OXA01	50	2.12±0.25	12.27±0.09(16.60)	12.68±0.14(30.89)	13.06±0.27(40.71)	13.48±0.22 (46.08)
OXA01	100	2.18±0.31	12.40±0.24(19.16)	12.66±0.10(28.04)	13.27±0.34(43.33)	13.78±0.02(52.32)
OXA02	50	2.19±0.09	12.27±0.27 (13.52)*	12.88±0.18(33.95)	13.10±0.09 (49.35)*	13.44±0.36 (49.33)*
OXA02	100	2.23±0.12	12.36±0.03(15.5)*	12.92±0.18 (29.17)*	13.24±0.14 (41.17)*	13.88±0.22(53.52)*
OXA03	50	2.23±.031	12.26±0.17 (11.32)	14.84±0.32 (63.92)	15.42±0.49 (68.85)	16.45±0.35 (75.42)
OXA03	100	2.11±0.19	12.43±0.36 (23.16)	16.14±0.17(75.63)	17.32±0.16(81.17)	18.14±0.12(85.07)
OXA04	50	2.18±0.25	12.50±0.21(22.8)**	12.72±0.12(29.85)**	12.96±0.49(36.35)**	13.56±0.31(48.76)**
OXA04	100	2.38±0.27	12.41±0.16(11.24)***	14.76±0.36(60)***	15.93±0.38(69.86)**	16.62±0.34(74.04)***
OXA05	50	2.34±0.43	12.44±0.14(14.09)	14.52±0.18(58.23)	15.58±0.57(68.06)	16.58±0.31(74.43)
OXA05	100	2.38±0.26	12.55±0.26(16.66)	16.24±0.29(71.85)	17.34±0.31(77.57)	18.04±0.28(80.39)
OXA06	50	2.19±0.09	12.27±0.27(13.52)	12.88±0.18(33.95)	13.10±0.09(49.35)	13.44±0.36(46.33)
OXA06	100	2.19±0.13	12.02±0.21(12.13)	14.32±0.18(53.96)	16.01±0.29(68.79)	17.42±0.15(72.66)
OXA07	50	2.31±0.29	12.36±0.32(12.11)	14.62±0.18(60)	15.35±0.25(66.82)	17.14±0.29(77.64)
OXA07	100	2.18±0.35	12.34±0.23(26)	16.75±0.24(77.70)	17.30±0.26(80.13)	19.42±0.43(86.20)
OXA08	50	2.12±0.25	12.27±0.09(26.60)***	12.68±0.14(36.89)**	13.06±0.27(49.71)**	13.48±0.22(59.18)***
OXA08	100	2.18±0.31	12.40±0.24(39.16)***	12.66±0.10(48.04)**	13.27±0.34(53.13)**	13.78±0.02(62.22)***
OXA09	50	2.24±0.26	12.36±0.11(15.08)	14.83±0.22(63.62)	15.60±0.22(70)	16.58±0.21(77.95)
OXA09	100	2.17±0.18	12.56±0.33(25.23)	16.24±0.31(75.22)	18.32±0.51(86.35)	19.71±0.12(88.6)

*Values are expressed as Mean ±SEM for 6 animals in each group. **P<0.01, *P<0.05 when compared with control*

Conclusion

This investigation demonstrates that imidazole-linked oxazolone derivatives represent a promising new class of analgesic and anti-inflammatory agents. The synthesized molecules were obtained in good yield and confirmed through comprehensive spectroscopic and analytical characterization. Toxicological evaluation confirmed excellent tolerability and a wide safety margin. Pharmacological screening revealed that OXA03, OXA05, OXA07, and particularly OXA09 produced potent central and peripheral analgesic activity, in several instances matching or surpassing reference NSAIDs. Molecular docking confirmed favorable COX-2 binding, especially for OXA04 and OXA08, supporting the hypothesis that the oxazolone framework is compatible with COX-2 active-site interactions. Collectively, the results suggest that these compounds can serve as potential lead structures for future NSAID development, combining strong efficacy, selectivity potential, and low acute toxicity. Further work—such as detailed SAR refinement, chronic toxicity testing, COX-1/COX-2 selectivity profiling, and mechanistic studies—is justified to advance these candidates toward clinical relevance.

Conflict of Interests

The authors declare no conflict of interest

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AI Tool Declaration

The authors declare that no AI and related tools are used to write the scientific content of this manuscript.

Data Availability

Data will be available on request

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